

ORIGINAL ARTICLE

A multicentre controlled study of the InLine radiofrequency ablation device for liver transection

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Abstract

Background. Surgical resection is the most effective therapy for liver cancer. Intraoperative blood loss during liver resection remains a major concern due to association with higher postoperative complications. The InLine radiofrequency ablation device (ILRFA) has achieved promising results in liver surgery with minimal blood loss and no increase of postoperative complications. In this multicentre controlled study, 108 patients undergoing liver resection were investigated. **Patients and methods.** A total of 108 patients underwent liver resections in 4 medical centres; the prospective sequential cohort study consisted of 54 ILRFA and 54 ultrasonic surgical aspirator transections as the control group. **Results.** The type of liver resection performed was very similar in both groups. The median number of RFA deployments was 3 (range 1–12) with a median coagulation time of 9 (range 3–36) min. Median blood loss was 165 ± 20 ml (range 5–675) in the ILRFA and 654 ± 83 ml (range 80–3600) in the control group ($p < 0.001$). The median transection time was 27 (2–219) min in the ILRFA group and 35 (5–62) min in controls. **Conclusions.** Our study indicates that ILRFA device for liver transection is effective in reducing blood loss and is safe. Precoagulation before parenchymal transection appears to be a valid concept in liver surgery. The avoidance of vascular inflow occlusion during parenchymal transection could also be of value.

Key Words: liver cancer, ILRFA, ultrasonic surgical aspirator, blood loss

Introduction

Surgical resection is the most effective therapy for selected patients with primary or secondary liver cancer [1,2]. With improvements in surgical techniques, advanced methods for hepatic transection and changes in postoperative management, surgical outcomes have been improved dramatically [3–5]. It has been reported that operative mortality and both overall and disease-free survival rates have improved over the past two decades [4,5]. However, intraoperative blood loss during liver resection remains a major concern due to association with higher postoperative complications [6]. This is especially problematic in cirrhotic, post chemotherapy and fatty liver [7–9]. Multiple techniques and devices have been used to reduce intraoperative blood loss, such as

the Pringle manoeuvre, total vascular exclusion, ultrasonic aspirator and water-jet cutter [10–13].

Radiofrequency ablation (RFA) is a relatively new technique, first used for the ablation of aberrant conduction pathways in the heart [14]. Application in liver tumours began in the 1990s, and the prevalence of RFA has been increasing rapidly because of its efficacy, safety and versatility [15]. Habib's group first described RFA-assisted liver resection; they used a monopolar RFA device to pre-coagulate liver before parenchymal transection and achieved significant reduction of blood loss (30 ± 10 ml) in 15 patients [16]. Recently, Morris and Daniel developed a novel bipolar multi-array RFA device – the InLine RFA device (ILRFA; Resect Medical, Fremont, CA, USA), which has achieved

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promising results in liver surgery with minimal blood loss and no increase of postoperative complications [17], but the clinical trials to date have been small in size. We designed this multicentre study to evaluate the effectiveness of ILRFA for the reduction of blood loss during liver transection in 108 patients, and also postoperative complications.

Patients and methods

Between November 2003 and November 2006, 108 patients underwent liver resections in 4 medical centres: St George Hospital (Sydney, Australia); University Hospital of the Saarland (Homburg, Germany); University of Hawaii and Kuakini Medical Center (Hawaii, USA) and Bassett Healthcare (Cooperstown, USA). The cohort study consisted of 54 patients who had undergone ILRFA precoagulation followed by ultrasonic surgical aspirator (USA) transection in 4 medical centres (ILRFA group) and 54 patients who had undergone USA transection as a control group in the Department of Surgery, St George Hospital, Sydney, Australia. These were prospective sequential series at St George Hospital. The patients' characteristics are shown in Table I.

Equipment

The ILRFA device consists of a linear array of six electrodes, each 4 cm or 6 cm long mounted on a 5 cm long plastic base (Figure 1). The InLine RFA device is compatible with a range of RFA generators, in this study the RITA® 1500 Generator (RITA Medical Systems, Mountain View, CA, USA) was used for producing power. This machine generates radiofrequency current at 460 KHz with a maximum power output of 150 W. The amount of power applied depended on the depth of resection. Table II shows

Table I. Demographics and preoperative assessment of ILRFA and control group.

Parameter	ILRFA group (n = 54)	Controls (n = 54)
Age (years)	63 (30–85)	62 (28–82)
Gender (M/F)	30/24	31/23
Diagnosis		
Colorectal cancer	40	36
Hepatocellular carcinoma	10	7
Cholangiocarcinoma	4	6
Adenoma	0	2
Breast cancer	0	1
Pancreatic cancer	0	1
Gallbladder cancer	0	1
Quality of liver		
Post chemotherapy	19	15
Steatosis	20	25
Cirrhosis	5	4

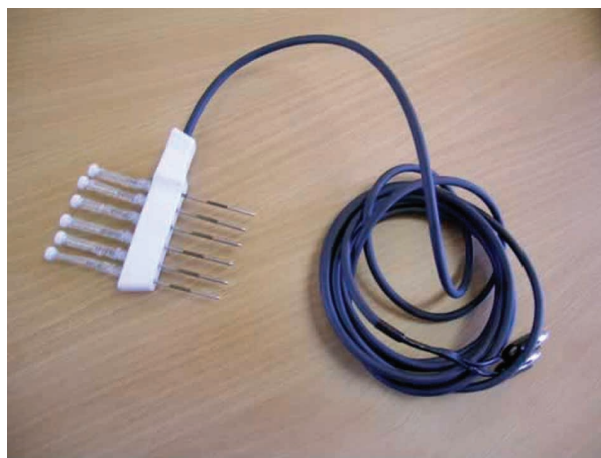


Figure 1. InLine RFA coagulator (ILRFA).

the protocol of power settings. The parenchymal transection was performed with an ultrasonic surgical aspirator (Selector® Integra NeuroSciences Ltd, Hampshire, UK).

Surgical procedures

All operations were performed under general anaesthesia after mobilization of the liver and intraoperative ultrasound. The Pringle manoeuvre was only applied in selected patients to minimize blood loss. During surgery, the resection plane was marked with diathermy; after RFA is used, the parenchyma is hardened and it is more difficult to feel the tumour edge or see it via ultrasound. We strongly recommend that intraoperative ultrasound is used before probe placement. This is particularly important when a vascular/biliary sheath crosses the resection plane which is to be retained and must be avoided. Then the ILRFA device was deployed in this marked line, often requiring several ILRFA placements to completely treat the resection plane (Figures 2 and 3). Finally, the liver parenchyma was transected with the USA. In the control group, only the USA was used for liver transection.

The volume of intraoperative blood loss was measured from the sum of the blood aspirated in the suction bottles and the blood loss as calculated by sponge weights. The surface area of each resection plane was then measured to allow calculation of the blood loss per cm² of liver transection. The time taken for transection was also recorded.

Statistical analysis

Statistical analysis was performed with SPSS for Windows (Version 12.0; SPSS Inc., Chicago, IL, USA). Student's *t* test, χ^2 , Mann–Whitney non-parametric test and Fisher's exact test were used as appropriate. Data are expressed as mean \pm standard deviation. *p* < 0.05 was considered statistically significant.

Table II. Power setting for RITA® 1500 generator.

Electrode deployment	Initial power setting (90 s)	Second power setting (60 s)	Final power setting (30 s)
1 cm	13	15	17
2 cm	27	30	33
3 cm	41	45	50
4 cm	54	60	66
5 cm	68	75	83
6 cm	77	85	94

Results

There was no mortality. The postoperative hospital stay was 10 ± 2 days. The surgical results are shown in Table III. The type of liver resection was very similar in both groups, including 14 non-anatomic and 40 anatomic resections (formal lobectomy or extended resection) in the ILRFA group, 18 non-anatomic and 36 anatomic resections in controls. The median number of RFA deployments was 3 (range 1–12) with a median coagulation time of 9 min (range 3–36). The transection time in ILRFA was slightly faster than that in controls: 24 min (range 2–219) vs 35 min (range 5–62), but this difference was not statistically significant. The mean intraoperative blood loss was 165 ± 20 ml (range 5–675) in the ILRFA

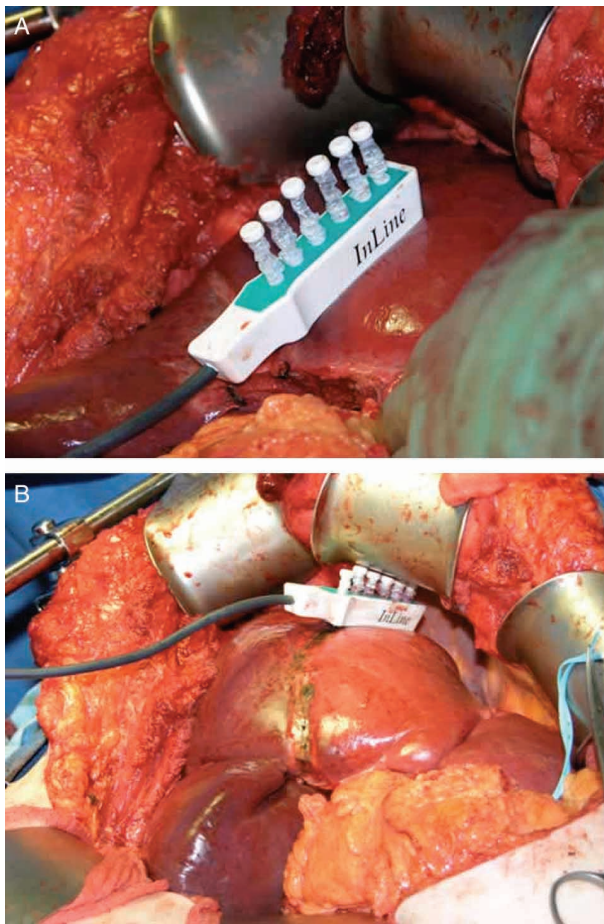


Figure 2. ILRFA deployment.

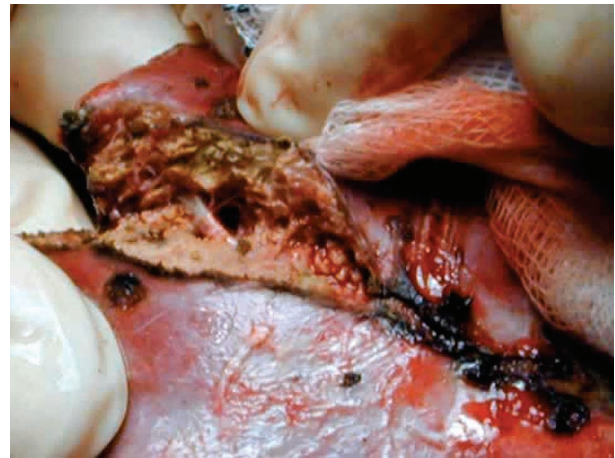


Figure 3. Avascular liver transection plane.

group and 654 ± 83 ml (range 80–3600) in the controls, a 74.8% reduction ($p < 0.001$) (Figure 4). The mean transection surface area was not different between the ILRFA and control groups. The mean transection blood loss per unit resection area was 3.29 ± 0.40 ml/cm² (range 0.14–12.33) in the ILRFA group compared with 6.41 ± 0.71 ml/cm² (range 0.92–36) in controls; the reduction was 48.7% ($p < 0.001$) (Figure 5). In the ILRFA group, only 6 (11.1%) transections were performed with a Pringle manoeuvre, whereas in the control group 32 (59.3%) Pringle manoeuvres were required ($p < 0.001$). Postoperative bile leak occurred in five patients (9.3%) following ILRFA compared with six (11.1%) in the control group.

Discussion

Surgical resection offers the best established curative treatment for patients with hepatocellular carcinoma or colorectal cancer liver metastases, which can result in significant long-term survival benefit in 20–25% of patients [18,19]. However, liver surgery is still associated with a morbidity rate of 30% and a mortality rate up to 5% [20,21]. Intraoperative blood loss remains a significant concern for surgeons operating on the liver. The mean blood loss has been reported to be between 600 and 1300 ml [21,22], with 28–47% of the patients requiring blood transfusion [21,23]. Several studies have shown that blood loss correlates adversely with length of hospital stay, complication rate and patient survival [24,25]. It also has been shown that patients requiring more than 10 units of blood after liver resection for colorectal cancer metastasis have an increased risk of tumour recurrence and poor survival, probably due to immunosuppression [26,27].

In this study, a multicentre controlled study was performed on ILRFA-assisted liver resection. A total of 108 patients underwent liver resection. The type of liver resection was very similar in both ILRFA and control groups, the hospital stay was almost the same,

Table III. Surgical results of ILRFA and control groups.

Parameter	ILRFA group (<i>n</i> = 54)	Control group (<i>n</i> = 54)	<i>p</i> value
Blood loss (ml)	165 ± 20	654 ± 83	<0.001
Resection time (min)	24 (2–219)	35 (5–62)	>0.05
Surface area (cm ²)	63.32 ± 6.18	103.87 ± 6.69	>0.05
Blood loss per cm ² (ml/cm ²)	3.29 ± 0.40	6.41 ± 0.71	<0.001
Type of resection			
Non-anatomical resection	14	18	
Anatomical resection (formal lobectomy or extended resection)	40	36	
Pringle manoeuvre	6	32	<0.001
Bile leak	5 (9.3%)	6 (11.1%)	

i.e. 10 ± 2 days. The transection time in the ILRFA group was only slightly faster than that of the controls, but at least it certainly does not take longer. The mean transection surface area was not different between the ILRFA and control groups ($p > 0.05$). Intraoperative blood loss was reduced dramatically in the ILRFA group, with a 74.8% reduction, and transection blood loss per unit resection area was also reduced significantly with a 48.7% reduction.

ILRFA is a bipolar RFA device which has several advantages over previous unipolar RFA devices. The unipolar probe has to be deployed many times to cover the designed resection plane, which necessarily makes a slow approach. On the contrary, ILRFA allows much more rapid (3 min for $6 \times 5 \times 1$ cm) and precise treatment. The resection plane then can be dissected almost bloodlessly with an ultrasonic surgical aspirator and only a few larger vessels and biliary ducts need to be ligated. Secondly, the bipolar device does not require grounding pads, because both electrodes are located on the probe and the alternating current circuit is confined within the target tissue [17].

The ILRFA device has shown promising results in liver surgery. We have shown that it can achieve haemostasis in the liver trauma setting [28]. Using ILRFA we were able to stop bleeding within 8 min with a 63.88% reduction of blood loss in a simulated sharp injury animal model. ILRFA may have other advantages. Vascular inflow occlusion (Pringle manoeuvre) is widely used in liver resection, but has been

associated with ischaemia-reperfusion injury. Using ILRFA vascular inflow occlusion may not be necessary any more. We were also concerned that an excess of bile leakage might be seen post ILRFA, but this was not the case. Constant et al. also reported that no postoperative bile leak occurred in their study using a RFA sealing device [29]. However, they used a relatively smaller animal model – swine weighing 29–36 kg. In our study, postoperative bile leak did occur in ILRFA in 5 (9.3%) of 54 patients, but was not increased compared to the control group with 6 (11.1%) of 54. Finally, the precise 1 cm zone of coagulative necrosis may allow for a transection plane that is relatively close to the tumour without jeopardizing radicality.

The surgical resection of cirrhotic liver does increase blood loss compared with normal liver [30]. The hilar dissection is more difficult with the surrounding fibrous liver and potentially deranged clotting, and cirrhotic liver is more vulnerable to ischaemia. Studies have shown that normal liver is able to tolerate continuous inflow occlusion for over 60 min, and intermittent occlusion for substantially longer [23,31]. However, cirrhotic liver can only tolerate ischaemic episodes of approximately 30 min with increased mortality and morbidity compared with normal liver [32]. When using ILRFA, surgeons only required vascular inflow occlusion in 11.1% of patients.

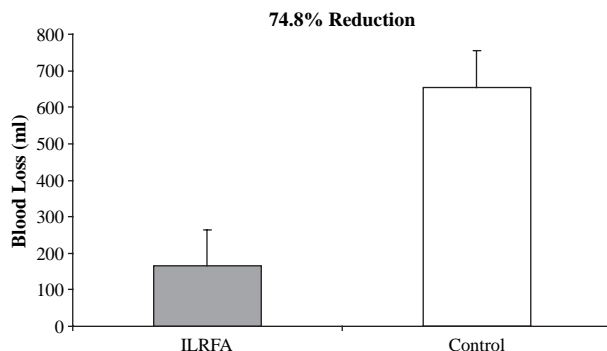


Figure 4. Comparison of intraoperative blood loss between ILRFA and control groups.

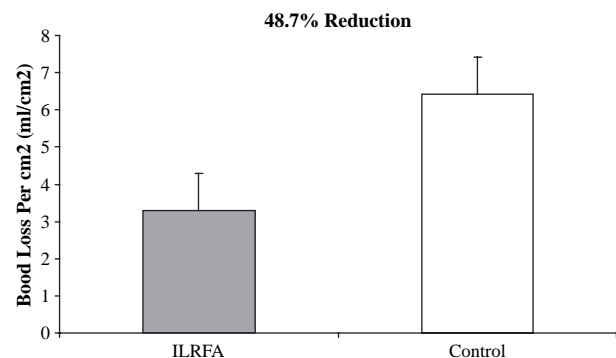


Figure 5. Comparison of intraoperative blood loss per cm² between ILRFA and control groups.

We accept that there are some limitations to this study. The patients were not randomly selected; the patients in the treatment group were based on criteria such as candidate for liver resection and available equipment. Also, we investigated the ILRFA group first, because we needed the data for the ILRFA-treated patients first. The control group originated from one hospital during the same period; however, we do not believe that there is a bias in this study. In conclusion, our study indicates that the ILRFA device is effective and safe for liver transection. Precoagulation before parenchymal transection appears to be a valid concept in liver surgery.

Acknowledgements and disclosures

No disclosures.

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